

**HYDROLOGIC AND HYDRAULIC ANALYSIS OF
DRAIN TILE REPLACEMENT ALTERNATIVES
WITHIN THE SKOKIE RIVER HEADWATERS**

Prepared For

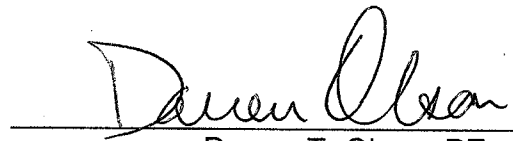
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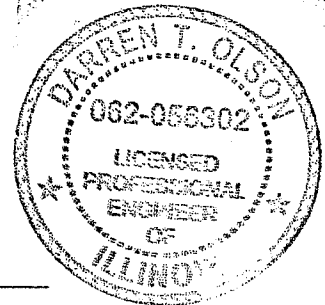
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INTRODUCTION

This report presents the results of a drain tile replacement study conducted by Christopher B. Burke Engineering, Ltd. (CBBEL) for the headwaters of the Skokie River in Lake County, Illinois. Currently, low flows in the headwaters of the Skokie River are conveyed by the existing drain tiles. Higher flows are conveyed overland, but many of the overland flow paths and channel have been filled in. The raised overland flow paths impound a significant amount of water to a depth of up to ten feet for events as frequent as the 10-year return interval storm event. This can be clearly seen on the FIS profiles, shown as Exhibit 3. Because the drain tiles in the headwaters are undersized and in poor condition, this area experiences frequent flooding, even during small storm events. The purpose of this study was to determine the possibility of replacing the failing tiles with larger pipes or portions of open channel that could reduce the frequency and depth of flooding in the headwaters.

The scope of the project includes the industrial area north of Washington Street in the Villages of Gurnee, Park City and Waukegan south to Rockland Road (Illinois Route 176) in Lake Forest, as shown on Exhibit 1. There are three sections of drain tile that are proposed to be replaced within the area:

- a 42-inch diameter Reinforced Concrete Pipe (RCP) upstream and downstream of Illinois Route 120 (Belvidere Road),
- a 24-inch diameter clay tile upstream and downstream of Casmir Pulaski Drive and
- dual 27-inch diameter clay tiles from upstream of Martin Luther King Drive (22nd Street) through the Navy Golf Course.

The tiles cannot be replaced with significantly larger pipes unless flood storage is provided to offset the increase in conveyance. In July 2006, STS Consultants, Ltd. performed a flood control feasibility study for SMC. The STS study investigated approximately 30 flood storage alternatives from upstream of Washington Street to Buckley Road (Illinois Route 137). Additionally, a future study will investigate flood storage at the Lake Bluff site, which is located adjacent to the Skokie River south of Illinois Route 176.

This study proposes six different drain tile replacement alternatives to alleviate the flooding in the headwaters. These alternatives use combinations of larger pipe sizes with various flood storage areas from the STS study and the Lake Bluff site.

EXISTING CONDITIONS

The existing conditions hydrologic and hydraulic models from the STS report were enhanced with survey information provided by James Anderson Company. These enhanced models served as the baseline conditions model and is the basis for comparison for the proposed alternatives analysis.

The existing conditions analysis consists of an iterative process between a HEC-1 hydrologic model, a HEC-2 hydraulic model, and a stage-discharge relationship for the drain tiles, overland flow paths and floodplain storage at Belvidere Road, Pulaski Road, and the Navy Golf Course. Each of these areas is represented by both a storage area in the HEC-1 hydrologic model and by cross-sections in the HEC-2 hydraulic model. Hydraflow Storm

Sewers computer software was used to generate the stage-discharge relationships for the drain tiles/overland flow paths at these locations for a variety of tailwaters.

The iterative analysis, which is consistent with the 2006 STS study, consists of the following steps:

- 1) Input stage-discharge relationships into the storage areas in the HEC-1 hydrologic model, assuming a tailwater elevation.
- 2) Use the resulting flowrates from the HEC-1 hydrologic model as inputs to the HEC-2 hydraulic model. The peak elevations from the storage areas in HEC-1 are input into the hydraulic model as "X5" cards at the upstream faces of the structures.
- 3) Compare the tailwaters from the results of the hydraulic model with the assumed tailwater in Step 1.
- 4) Repeat Steps 1 - 3 until assumed tailwaters match the tailwaters resulting from the HEC-2 hydraulic model.

The existing conditions hydrologic and hydraulic analysis was completed for the 2-, 10-, 50-, and 100-year return interval using the 12-hour duration, which is the critical duration storm event from the 2006 STS study. The rainfall depths for these storm events are taken from Bulletin 70. A comparison between CBBEL's existing conditions analysis, the baseline conditions model from the STS report, and FIS profile is presented in Table 1.

Table 1
Comparison of CBBEL/STS/FIS Existing Conditions Results

2-Year, 12 Hour Storm Event			
Location	CBBEL Headwater Elevation (ft)	STS Headwater Elevation (ft)	FIS Headwater Elevation (ft)
Belvidere Road	695.62	695.59	696.20
Pulaski Road	693.23	693.39	693.40
MLK/Navy Golf Course	687.50	690.00	690.57
10-Year, 12 Hour Storm Event			
Location	CBBEL Headwater Elevation (ft)	STS Headwater Elevation (ft)	FIS Headwater Elevation (ft)
Belvidere Road	696.37	696.60	696.48
Pulaski Road	694.14	694.44	695.02
MLK/Navy Golf Course	688.59	690.44	691.01
50-Year, 12 Hour Storm Event			
Location	CBBEL Headwater Elevation (ft)	STS Headwater Elevation (ft)	FIS Headwater Elevation (ft)
Belvidere Road	696.86	696.98	696.65
Pulaski Road	695.91	695.80	695.83
MLK/Navy Golf Course	689.99	690.98	691.32

100-Year, 12 Hour Storm Event			
Location	CBBEL Headwater Elevation (ft)	STS Headwater Elevation (ft)	FIS Headwater Elevation (ft)
Belvidere Road	697.04	697.17	698.14
Pulaski Road	696.49	696.30	696.45
MLK/Navy Golf Course	690.47	691.30	691.82

The comparison made in Table 1 shows that the results obtained in the 2006 STS study and FIS profile generally agree with those determined in the CBBEL study for the 100-year flood profile. One exception to this is noted for headwater elevations at Martin Luther King Jr. Drive/Navy Golf Course. The CBBEL study accounted for a 36-inch diameter storm sewer located in the Navy Golf Course and also included an additional overflow on the Abbott property based on survey information provided by James Anderson Company. The STS and FIS studies did not account for this additional conveyance at the Navy Golf Course. The effects of the additional pipe and alternate overflow route have a significant impact on flood elevations between Pulaski Road and the Navy Golf Course.

PROPOSED CONDITIONS

The purpose of the proposed conditions analysis is to determine the effectiveness of six drain tile replacement alternatives that combine possible flood storage locations and larger pipe sizes throughout the headwaters of the Skokie River. The flood storage locations have been previously analyzed as part of the 2006 STS study, and range from gravity, on-line flood storage to pumped, off-line flood storage. The six proposed drain tile replacement alternatives were chosen to cover a wide range of scenarios, from a scenario where no additional flood storage is provided to the scenario where the maximum amount of available flood storage is provided. The proposed improvements were designed to meet public flood control project permitting requirements of SMC and the Illinois Department of Natural Resources – Office of Water Resources (IDNR-OWR). These requirements are considered met if the proposed project will not increase flood heights outside of easements for all flood events up to and including the base flood event.

Alternative #1: No Additional Storage in Watershed

This alternative assumed that no future storage from the STS study or at the Lake Bluff site would be placed in the watershed. The proposed replacement drain tile sizes were increased in size until the flood elevations downstream of the Navy Golf Course were increased a maximum of 0.1 ft outside of the channel banks (the maximum threshold allowed by SMC for a public flood control project). The proposed improvements consist of the following:

- Replacing the existing drain tile under Pulaski Road with a 36-inch diameter pipe.
- Replacing the existing drain tile under Martin Luther King Jr. Drive and the Navy Golf Course with a 42-inch diameter pipe (36-inch diameter storm sewer located in the Navy Golf Course was assumed to remain).

The proposed improvements for this alternative are shown on Exhibit 4. The results of this analysis are shown in Table 2.

Table 2
Comparison of Alternative #1 Results

2-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	695.62	695.62	0.00
Pulaski Road	692.95	693.23	0.28
MLK/Navy Golf Course	687.20	687.50	0.30
10-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	696.37	696.37	0.00
Pulaski Road	693.91	694.14	0.23
MLK/Navy Golf Course	688.34	688.59	0.25
50-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	696.86	696.86	0.00
Pulaski Road	695.73	695.91	0.18
MLK/Navy Golf Course	689.95	689.99	0.04
100-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	697.04	697.04	0.00
Pulaski Road	696.29	696.49	0.20
MLK/Navy Golf Course	690.35	690.47	0.12

As shown in Table 2, the resultant flood profiles indicate that the 2-year return interval flood profiles in the headwaters decreased by up to 0.3 ft and the 100-year flood profile decreased by up to 0.2 ft. The resultant reduction in the footprint of the 100-year floodplain is negligible.

Alternative #2: Maximum Increase in Watershed Storage:

This alternative assumed that the maximum amount of future flood storage in the headwaters from the 2006 STS report and at the Lake Bluff site would be constructed. The proposed drain tiles were increased in size until the floodplain in the headwaters were primarily contained within the channel banks. The proposed improvements for this alternative, which are shown on Exhibit 5, consist of the following:

- Adding two supplemental 60-inch diameter storm sewers under Belvidere Road (the existing tile system at this location is composed largely of RCP in good condition, so it is not proposed to be replaced).
- Replacing the drain tile under Pulaski Road with two 12-foot by 4-foot box culverts (equivalent to five 60-inch diameter circular pipes).
- Replacing drain tile under Martin Luther King Jr. Drive with two 12-foot by 5-foot box culverts (equivalent to seven 60-inch diameter circular pipes; 36-inch diameter storm sewer located in the Navy Golf Course was assumed to remain).

- Adding 38 acre-feet of flood storage at Skokie Headwaters Site A (Option 4A from 2006 STS report).
- Adding 290 acre-feet of flood storage at Skokie Headwaters Site B (Option 4B from 2006 STS report).
- Adding 220 acre-feet of flood storage at North Chicago Site 1 (Option 1D from 2006 STS report).
- Adding 37 acre-feet of flood storage at North Chicago Site 3 (Option 3C from 2006 STS report).
- Adding 259 acre-feet of flood storage at the Lake Bluff site.

These improvements will require a significant expenditure for storm sewers and flood storage. In certain locations, these improvements will not fit within the district's existing drainage easements and creating an open channel may be more cost-effective than the multiple box culverts required to produce the desired flood reductions. As shown in Table 3, the resultant flood profiles indicate that the 2-year return interval flood profiles in the headwaters decreased by up to 5.9 ft and the 100-year flood profile decreased by up to 5.8 ft. The resultant reduction in the footprint of the 100-year floodplain is significant. This alternative results in increases in flood flows and floodwater elevations between IL 137 and the proposed Lake Bluff site. To meet the SMC permit requirements for a public flood control project, it would require easements, channel improvements, and/or culvert replacements between IL137 and the proposed Lake Bluff site.

Table 3
Comparison of Alternative #2 Results

2-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	690.56	695.62	5.06
Pulaski Road	688.27	693.23	4.96
MLK/Navy Golf Course	681.65	687.50	5.85
10-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	690.85	696.37	5.52
Pulaski Road	689.50	694.14	4.64
MLK/Navy Golf Course	682.39	688.59	6.20
50-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	691.74	696.86	5.12
Pulaski Road	690.40	695.91	5.51
MLK/Navy Golf Course	685.05	689.99	4.94
100-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	692.72	697.04	4.32
Pulaski Road	690.72	696.49	5.77
MLK/Navy Golf Course	686.29	690.47	4.18

Alternative #2A: Alternative #2 with Proposed Navy Golf Course Overflow

To reduce the pipe sizes required under Alternative #2, a 43-foot wide trapezoidal overflow channel through the Abbott Property adjacent to the Navy Golf Course is proposed under this scenario. Instead of dual 12-foot by 5-foot box culverts under Martin Luther King Jr. Drive, one 12-foot by 5-foot box culvert would be required in addition to the 43-foot wide trapezoidal channel through the Abbott Property. The overflow channel is shown on Exhibit 10 and would require easements from Abbott Laboratories, ComEd, and the North Shore Sanitary District. As shown in Table 4, the floodplain reduction benefits associated with Alternative #2A are similar to those in Alternative #2.

Table 4
Comparison of Alternative #2A Results

2-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	690.56	695.62	5.06
Pulaski Road	688.27	693.23	4.96
MLK/Navy Golf Course	681.65	687.50	5.85
10-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	690.85	696.37	5.52
Pulaski Road	689.50	694.14	4.64
MLK/Navy Golf Course	684.35	688.59	4.24
50-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	691.74	696.86	5.12
Pulaski Road	690.40	695.91	5.51
MLK/Navy Golf Course	686.06	689.99	3.93
100-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	692.72	697.04	4.32
Pulaski Road	690.84	696.49	5.65
MLK/Navy Golf Course	686.61	690.47	3.86

Alternative #3: Lake Bluff Storage Only:

This alternative assumes that no future storage will be placed in the watershed other than the Lake Bluff site and gravity on-line flood storage at Skokie Headwaters Site A. Site A storage was therefore included in this analysis. The drain tiles were increased in size until the flood profiles in the headwaters were primarily contained within the channel banks. The increase in flood flows within the watershed will be stored at the future Lake Bluff site. At the time of the report writing, the City of Waukegan received some grant money for the flood storage of Site A. This alternative will also likely require easements or culvert replacements

between IL137 and the proposed Lake Bluff site. The proposed improvements for this alternative, which are shown on Exhibit 6, consist of the following:

- Adding three supplemental 12-foot by 5-foot box culverts at Belvidere Road (equivalent to ten 60-inch diameter circular pipes).
- Replacing the existing drain tile under Pulaski Road with five 12-foot by 4-foot box culverts (equivalent to 13 60-inch diameter circular pipes).
- Replacing the existing drain tile under Martin Luther King Jr. Drive with five 12-foot by 6-foot box culverts (equivalent to 19 60-inch diameter circular pipes; 36-inch drain tile located in the Navy Golf Course was assumed to remain).
- Adding 27 acre-feet of flood storage at Skokie Headwaters Site A (Option 2A from 2006 STS report).
- Adding 706 acre-feet of flood storage at the Lake Bluff site.

Table 5
Comparison of Alternative #3 Results

2-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	691.85	695.62	3.77
Pulaski Road	689.48	693.23	3.75
MLK/Navy Golf Course	682.24	687.50	5.26
10-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	691.89	696.37	4.48
Pulaski Road	689.95	694.14	4.19
MLK/Navy Golf Course	684.62	688.59	3.97
50-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	692.50	696.86	4.36
Pulaski Road	691.54	695.91	4.37
MLK/Navy Golf Course	685.51	689.99	4.48
100-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	693.31	697.04	3.73
Pulaski Road	692.52	696.49	3.97
MLK/Navy Golf Course	686.03	690.47	4.44

These improvements will require a significant expenditure for storm sewers and flood storage. In certain locations, these improvements will not fit within the district's existing drainage easements and creating an open channel may be more cost-effective than the multiple box culverts required to produce the desired flood reductions. As shown in Table 5, the resultant flood profiles indicate that the 2-year return interval flood profiles in the headwaters decreased by up to 5.3 ft and the 100-year flood profile decreased by up to 4.4 ft. The resultant reduction in the footprint of the floodplain is significant. This alternative results in increases in flood flows and floodwater elevations between IL 137 and the proposed Lake Bluff site. To meet the SMC permit requirements for a public flood control

project, it would require easements, channel improvements, and/or culvert replacements between IL137 and the proposed Lake Bluff site.

Alternative #3A: Alternative #3 with Proposed Navy Golf Course Overflow

To reduce the pipe sizes required under Alternative #3, a 43-foot wide trapezoidal overflow channel through the Abbott Property adjacent to the Navy Golf Course is proposed under this scenario. Instead of five 12-foot by 6-foot box culverts under Martin Luther King Jr. Drive, four 12-foot by 4-foot box culverts would be required in addition to the 43-foot wide trapezoidal channel through the Abbott Property. The overflow channel is shown on Exhibit 10 and would require easements from Abbott Laboratories, ComEd, and the North Shore Sanitary District. As shown in Table 6, the floodplain reduction benefits associated with Alternative #3A are similar to those in Alternative #3.

Table 6
Comparison of Alternative #3A Results

2-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	691.85	695.62	3.77
Pulaski Road	689.48	693.23	3.75
MLK/Navy Golf Course	682.29	687.50	5.21
10-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	691.89	696.37	4.48
Pulaski Road	689.95	694.14	4.19
MLK/Navy Golf Course	684.63	688.59	3.96
50-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	692.50	696.86	4.36
Pulaski Road	691.54	695.91	4.37
MLK/Navy Golf Course	685.80	689.99	4.19
100-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	693.31	697.04	3.73
Pulaski Road	692.52	696.49	3.97
MLK/Navy Golf Course	686.14	690.47	4.33

Alternative #4: Headwaters Storage and no Lake Bluff Storage:

This scenario assumed that the maximum amount of future storage from the STS report is placed at Skokie Headwaters Site A and North Chicago Site 1, half of the maximum storage is placed at Skokie Headwaters Site B and North Chicago Site 3, and there will be no storage available at the Lake Bluff site. The drain tiles were increased in size until the flood elevations downstream of the Navy Golf Course are increased a maximum of 0.1 ft outside of the channel banks (the maximum threshold allowed by SMC for a public flood control

project). The proposed improvements for this alternative, which are shown on Exhibit 7, consist of the following:

- Adding a supplemental 24-inch diameter storm sewer at Belvidere Road.
- Replacing drain tile under Pulaski Road with a 48-inch diameter pipe.
- Replacing drain tile under Martin Luther King Jr. Drive a 48-inch diameter pipe (36-inch diameter drain tile located in the Navy Golf Course was assumed to remain).
- The addition of 27 acre-feet of flood storage at Skokie Headwaters Site A (Option 2A from 2006 STS report).
- The addition of 78 acre-feet of flood storage at Skokie Headwaters Site B (Half of Option 1B from 2006 STS report).
- The addition of 90 acre-feet of flood storage at North Chicago Site 1 (Option 1A from 2006 STS report).
- The addition of 23 acre-feet of flood storage at North Chicago Site 3 (Half of Option 3A from 2006 STS report).

Table 7
Comparison of Alternative #4 Results

2-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	695.38	695.62	0.24
Pulaski Road	691.92	693.23	1.31
MLK/Navy Golf Course	686.83	687.50	0.67
10-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	696.25	696.37	0.12
Pulaski Road	693.20	694.14	0.94
MLK/Navy Golf Course	687.93	688.59	0.66
50-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	696.40	696.86	0.46
Pulaski Road	694.67	695.91	1.24
MLK/Navy Golf Course	689.63	689.99	0.36
100-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	696.75	697.04	0.29
Pulaski Road	695.41	696.49	1.08
MLK/Navy Golf Course	690.21	690.47	0.26

As shown in Table 7, the resultant flood profiles indicate that the 2-year return interval flood profiles in the headwaters decreased by up to 1.3 ft and the 100-year flood profile decreased by up to 1.1 ft. The resultant reduction in the footprint of the 100-year floodplain is only significant for the area just upstream of Pulaski Road.

Alternative #5: Headwaters Storage and Lake Bluff Storage

This scenario included various storage locations throughout the headwaters and at the Lake Bluff site. The drain tiles at Belvidere Road, Pulaski Drive, and Martin Luther King Jr. Drive were increased in size. This alternative assumes that the increases in flowrates due to the larger pipe sizes will be offset by storage available at the Lake Bluff site. The proposed improvements for this alternative, which are shown on Exhibit 8, consist of the following:

- Adding two supplemental 60-inch diameter storm sewers at Belvidere Road.
- Replacing drain tile under Pulaski Road with two 12-foot by 4-foot box culverts.
- Replacing drain tile under Martin Luther King Jr. Drive with four 66-inch diameter pipes (36-inch diameter drain tile located in the Navy Golf Course was assumed to remain).
- Adding 38 acre-feet of flood storage at Skokie Headwaters Site A (Option 4A from 2006 STS report).
- Adding 290 acre-feet of flood storage at Skokie Headwaters Site B (Option 4B from 2006 STS report).
- Adding 220 acre-feet of flood storage at North Chicago Site 1 (Option 1D from 2006 STS report).
- The addition of 280 acre-feet of flood storage at the Lake Bluff site.

Table 8
Comparison of Alternative #5 Results

2-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	690.61	695.62	5.01
Pulaski Road	688.34	693.23	4.89
MLK/Navy Golf Course	681.65	687.50	5.85
10-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	690.88	696.37	5.49
Pulaski Road	689.50	694.14	4.64
MLK/Navy Golf Course	683.74	688.59	4.85
50-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	691.80	696.86	5.06
Pulaski Road	689.87	695.91	6.04
MLK/Navy Golf Course	686.36	689.99	3.63
100-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	692.91	697.04	4.13
Pulaski Road	690.54	696.49	5.95
MLK/Navy Golf Course	687.60	690.47	2.87

These improvements will require a significant expenditure for storm sewers and flood storage. In certain locations, these improvements will not fit within the district's existing drainage easements and creating an open channel may be more cost-effective than the multiple pipes required to produce the desired flood reductions. As shown in Table 8, the resultant flood profiles indicate that the 2-year return interval flood profiles in the headwaters decreased by up to 5.9 ft and the 100-year flood profile decreased by up to 6.0 ft. The resultant reduction in the footprint of the 100-year floodplain is significant. This alternative results in increases in flood flows and floodwater elevations between IL 137 and the proposed Lake Bluff site. To meet the SMC permit requirements for a public flood control project, it would require easements, channel improvements, and/or culvert replacements between IL137 and the proposed Lake Bluff site.

Alternative #5A: Alternative #5 with Proposed Navy Golf Course Overflow

To reduce the pipe sizes required under Alternative #5, a 43-foot wide trapezoidal overflow channel through the Abbott Property adjacent to the Navy Golf Course is proposed under this scenario. Instead of four 66-inch diameter culverts under Martin Luther King Jr. Drive, three 66-inch diameter culverts would be required in addition to the 43-foot wide trapezoidal channel through the Abbott Property. The overflow channel is shown on Exhibit 10 and would require easements from Abbott Laboratories, ComEd, and the North Shore Sanitary District. As shown in Table 9, the floodplain reduction benefits associated with Alternative #5A are similar to those in Alternative #5.

Table 9
Comparison of Alternative #5A Results

2-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	690.61	695.62	5.01
Pulaski Road	688.34	693.23	4.89
MLK/Navy Golf Course	681.65	687.50	5.85
10-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	690.88	696.37	5.49
Pulaski Road	689.50	694.14	4.64
MLK/Navy Golf Course	684.36	688.59	4.23
50-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	691.80	696.86	5.06
Pulaski Road	689.87	695.91	6.04
MLK/Navy Golf Course	686.37	689.99	3.62
100-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	692.91	697.04	4.13
Pulaski Road	690.54	696.49	5.95
MLK/Navy Golf Course	686.95	690.47	3.52

Alternative #6: Headwaters Storage with 72-Inch Pipe through Navy Golf Course

This scenario assumed that the online wetland storage is available at Skokie Headwaters Site A and half of the maximum storage is placed at Skokie Headwaters Site B. The drain tiles at Pulaski Road and Martin Luther King Jr. Drive were increased in size but the existing drain tile at Belvidere Road will remain. This alternative assumes that the increases in flowrates due to the larger pipe sizes will be offset by storage available at the Lake Bluff site. The proposed improvements for this alternative, which are shown on Exhibit 9, consist of the following:

- Replacing drain tile under Pulaski Road with a 54-inch diameter pipe.
- Replacing drain tile under Martin Luther King Jr. Drive with a 72-inch diameter pipe (36-inch diameter drain tile located in the Navy Golf Course was assumed to remain).
- The addition of 27 acre-feet of flood storage at Skokie Headwaters Site A (Option 2A from 2006 STS report).
- The addition of 78 acre-feet of flood storage at Skokie Headwaters Site B (Half of Option 1B from 2006 STS report).
- The addition of 76 acre-feet of flood storage at the Lake Bluff site

Table 10
Comparison of Alternative #6 Results

2-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	695.37	695.62	0.25
Pulaski Road	691.00	693.23	2.23
MLK/Navy Golf Course	684.04	687.50	3.46
10-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	696.23	696.37	0.14
Pulaski Road	692.93	694.14	1.21
MLK/Navy Golf Course	686.22	688.59	2.37
50-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	696.42	696.86	0.44
Pulaski Road	694.31	695.91	1.60
MLK/Navy Golf Course	689.14	689.99	0.85
100-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	696.78	697.04	0.26
Pulaski Road	695.13	696.49	1.36
MLK/Navy Golf Course	689.94	690.47	0.53

As shown in Table 10, the resultant flood profiles indicate that the 2-year return interval flood profiles in the headwaters decreased by up to 3.5 ft and the 100-year flood profile decreased by up to 1.4 ft. The resultant reduction in the footprint of the 100-year floodplain is significant for the area between Pulaski Road and Martin Luther King Jr. Drive/Navy Golf Course. This alternative results in increases in flood flows and floodwater elevations between IL 137 and the proposed Lake Bluff site. To meet the SMC permit requirements for a public flood control project, it would require easements, channel improvements, and/or culvert replacements between IL137 and the proposed Lake Bluff site.

Alternative #6A: Alternative #6 with Proposed Navy Golf Course Overflow

Under this alternative, a 43-foot wide trapezoidal overflow channel through the Abbott Property adjacent to the Navy Golf Course will be added along with the 72-inch diameter pipe in this area. The overflow channel is shown on Exhibit 10 and would require easements from Abbott Laboratories, ComEd, and the North Shore Sanitary District. As shown in Table 11, there is a significantly greater floodplain reduction at Martin Luther King Jr. Drive/Navy Golf Course associated with this alternative. Otherwise, the floodplain reduction benefits associated with Alternative #6A are similar to those in Alternative #6.

Table 11
Comparison of Alternative #6A Results

2-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	695.37	695.62	0.25
Pulaski Road	691.00	693.23	2.23
MLK/Navy Golf Course	684.04	687.50	3.46
10-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	696.23	696.37	0.14
Pulaski Road	692.61	694.14	1.53
MLK/Navy Golf Course	685.63	688.59	2.96
50-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	696.40	696.86	0.46
Pulaski Road	694.02	695.91	1.89
MLK/Navy Golf Course	687.08	689.99	2.91
100-YR, 12-Hour Storm Event			
Location	Proposed Headwater Elevation (ft)	Existing Headwater Elevation (ft)	Difference (feet)
Belvidere Road	696.76	697.04	0.28
Pulaski Road	694.94	696.49	1.55
MLK/Navy Golf Course	687.65	690.47	2.82

Restrictor Sizing Analysis

For each of the proposed drain tile replacement alternatives that include future flood storage, restrictors will be placed on the larger pipes until the flood storage is constructed within the watershed. Because the existing pipe under Belvidere Road is in good condition, it was assumed to remain under all proposed alternatives. Therefore, the supplemental pipes that are proposed at Belvidere Road will be completely blocked off until the flood storage is constructed. However, because the drain tiles under Pulaski Road and Martin Luther King Jr. Drive will be entirely replaced with larger pipes, restrictors will be needed at these locations to mimic the existing drain tile system until the flood storage becomes available. Table 12 summarizes the results of the restrictor sizing analysis. It should be noted that in the case of the drain tile being replaced with multiple pipes, the restrictors will be placed on one of the proposed pipes, while the other pipe(s) will be completely blocked.

Table 12
Summary of Restrictor Sizing Results

Location	Pulaski Road	MLK/Navy Golf Course
Orifice #1 Diameter (inches)	10.7	12.0
Orifice #2 Invert (ft)	683.94	678.97
Orifice #2 Diameter (inches)	9.3	14.7
Orifice #2 Invert (ft)	687.18	678.97

SUMMARY OF RESULTS

The alternatives analysis performed for this study was to assess the effectiveness of proposed drain tile replacement projects in the headwaters of the Skokie River. The alternatives were designed to span a wide range of pipes sizes and potential flood storage options. The potential flood storage sites were taken from the previous STS study and at the Lake Bluff site. All alternatives were designed in accordance with SMC permit requirements for public flood control projects, however, Alternatives 2,3,5, and 6 will require easements, channel improvements, and/or culvert replacements between IL 137 and the Lake Bluff site. The reduction in floodplain elevations in the headwaters varies from a negligible decrease to a decrease of several feet. The 100-year floodplain reduction benefits of each alternative are summarized in Appendix 1. The maps showing the reduction in the footprint of the 100-year floodplain are enclosed as Exhibit 4-9. Based on the information contained in this report, the following conclusions can be made:

- To achieve significant reduction in flood elevations throughout headwaters, major drainage improvements are required. These include large pipes and storage areas that may not fit in the district's current drainage easements.

- Significant floodplain reductions in the headwaters are likely not permissible without providing some flood storage at the Lake Bluff site.
- If flood storage sites are not available the deteriorating tiles can still be replaced with larger pipes than exist currently (Alternative 1).

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